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Vector Manifestation in Hot Matter *)

—— *Formulation and Predictions* ——

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In this write-up, I list the key ingredients for formulating the vector manifestation in hot matter together with several predictions made so far.

§1. Introduction

The vector manifestation (VM) was proposed[1),2)] as a novel manifestation in which the chiral symmetry is restored by the massless degenerate pseudoscalar meson and the vector meson as the chiral partner. In Ref. 3), it was shown how the VM is formulated in hot matter using the effective field theory for π and ρ based on the hidden local symmetry (HLS).[6)] In this write-up I shall list the key points for the formulation and several predictions. For details please see the relevant references.

§2. Formulation of the vector manifestation in hot matter

The key ingredients to formulate the VM in hot matter are the fixed point structure of the renormalization group equations (RGEs) for the parameters in the HLS and the *intrinsic temperature dependences* of the parameters determined through the Wilsonian matching.[7)] The coupled RGEs for the HLS gauge coupling g and the parameter a have the fixed point characterized by $(g, a) = (0, 1)$. The intrinsic temperature dependence introduced through the Wilsonian matching is nothing but the signature that hadron has an internal structure constructed from the quarks and gluons. This is similar to the situation where the coupling constants among hadrons are replaced with the momentum-dependent form factor in high energy region. Thus the intrinsic thermal effects play more important roles in higher temperature region, especially near the critical temperature.

The formulation of the VM in hot matter is roughly sketched as follows:[3),4)] The restored chiral symmetry implies that, at the critical temperature T_c, the vector current correlator must agree with the axial vector current correlator. The requirement of the equality between two correlators implies that the bare g and a satisfy $(g_{\rm bare}, a_{\rm bare}) = (0, 1)$. Since $(g, a) = (0, 1)$ is the fixed point of the RGEs for g and a, $(g_{\rm bare}, a_{\rm bare}) = (0, 1)$ implies that $(g, a) = (0, 1)$ is satisfied at any energy scale. As a result, the quantum correction to the ρ mass as well as the hadronic thermal

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correction disappears at T_c since they are proportional to the gauge coupling g. The bare ρ mass, which is also proportional to $g_{\rm bare}$, vanishes at T_c. These imply that the pole mass of the ρ meson also vanishes at T_c.

I would like to note that the VM in dense matter can be formulated in a similar way,[8)] where the *intrinsic density dependence* plays an important role.

§3. Predictions of the vector manifestation in hot matter

There are several predictions of the VM in hot matter made so far.

In Ref. 5), the vector and axial-vector susceptibilities were studied. It was shown that the equality between two susceptibilities are satisfied and that the VM predicts $\chi_A = \chi_V = \frac{2}{3}\,T_c^2$ for $N_f = 2$, which is in good agreement with the result obtained in the lattice simulation.[9)]

In Ref. 4), a prediction associated with the validity of vector dominance (VD) in hot matter was made: As a consequence of including the intrinsic effect, the VD is largely violated at the critical temperature. This indicates that the assumption of the VD, which was made in the analysis on the dilepton spectra carried out in hot matter such as in Ref 10), may need to be weakened, at least in some amounts, for consistently including the effect of the dropping ρ mass such as the one predicted by the Brown-Rho scaling[11)] into the analysis.

In addition to the above predictions, the pion velocity was studied including the effect of Lorentz symmetry breaking,[12),13)] which is reported in the write-up by Chihiro Sasaki.[14)]

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